Paint application has an important influence on the life of a paint system and must be properly controlled to ensure that coatings attain their full potential. This is achieved by employing skilled operatives and ensuring that paint is applied correctly.

Despite the improvements that have taken place which allow for more economic application, the older methods are still widely used. Methods such as brush application are basically simple but still require to be properly controlled if good coatings are to be obtained. Furthermore, well-trained painters are far more likely to produce sound coatings than those with little knowledge of paint application.

In this chapter, only the application methods commonly used to paint constructional steelwork will be considered in detail. Methods used to apply paints to domestic equipment, cars and consumer goods are not used to any extent for constructional work. Furthermore, they are applied under factory-controlled conditions to the manufacturers’ specifications, which cannot easily be varied by the purchaser.

5.1 Methods of application

The methods used for paint application fall into the following general categories:

(a) manual application – brush and roller;
(b) spray – airspray and airless, hot or cold;
(c) dip coating;
(d) flow coating;
(e) roller coating;
(f) electrostatic;
(g) powder coating.

Additionally, paint coatings may be air-dried or stoved.

For constructional steelwork, methods (a) and (b) are generally used for
applying paint. Method (e) is sometimes used and (f) and (g) may be used, but generally are only for special components or for plastic coatings.

5.1.1 Brush application

Although centuries old, application of paint by brushing is still widely used, e.g. for:

(a) Sensitive areas, i.e. close to property, equipment, etc. where overspray could cause a problem.
(b) Small or irregular surfaces, such as lattice structures, pipe racks, etc.
(c) Interior areas with relatively poor ventilation.
(d) Application to surfaces with an unavoidable low standard of preparation. The brush will tend to penetrate into pits and, to a certain extent, displace dust and even moisture.
(e) Small areas of touch-up work.

Other important advantages of the use of brushes are their relative cheapness and ease of cleaning.

The brush serves two purposes. It acts as the container for the paint as it is transferred from the can or kettle and also as the actual method of transfer. This means that the bristles must be capable of holding sufficient paint to allow for reasonable coverage at each transfer and must also be of material capable of transferring the paint in an even way through the points of contact at the steel surface. It is important to choose the right type of brush for the job in hand. For example: square-ended brushes for large flat surfaces, angular-cut brushes for narrow surfaces and oval shaped brushes for small surfaces such as nuts and bolts. Top quality brush bristles are made from animal hairs and are flagged, i.e. have split ends. Brushes made from polyester or nylon have better wearing properties but give a lower standard of finish. They should be used, however, for water-borne paints. Cheap brushes of any type often end up costing more when one takes into consideration productivity, brush life and the possible need to rework areas of poor quality.

Apart from the conventional brush described above, another type made from short synthetic fibres about 1⅛in (3.2cm) long attached to a flat base about 4in (10.2cm) × 6in (15.2cm) is also used. This holds more paint and covers a greater area. It is particularly useful for forcing paint into crevices and for use where it is difficult to apply the paint in the conventional manner.

Various attempts have been made to mechanise the process by using methods such as hoses to supply the paint to the brush. Recently, equipment of this type has been made available for the application of emulsion paints for the domestic market. Generally, such methods are
not widely used for the painting of steel. In part this arises from the additional cleaning of equipment required, so eliminating one of the main advantages of brush application. Additionally, skilled painters used to application with conventional brushes appear to find that they lose some of the control over the operation if the paint is automatically fed to the brush. The advantages of brush application are considered to be as follows:

(i) Cheap, requiring no expensive equipment.
(ii) Relatively clean, requiring no masking of adjacent areas.
(iii) Can be used in restricted areas.
(iv) Particularly suitable for displacing dust and moisture on imperfectly prepared surfaces.
(v) Allows paint to be worked into crevices and other difficult areas.
(vi) Brushes are easily cleaned and can be easily maintained in good condition.
(vii) The only practicable method of applying certain types of paint, e.g. lead-based.

The main disadvantage is the slow rate of application, which can be less than 10% of the rate achieved by spray methods. However, taking into account the time saved on masking, cleaning, etc., the overall rate of application is better than this figure would indicate. It is also generally used for stripe coats along edges, corners, etc., even where other methods may be used for the application of paint to the main areas.

In general, literature and paint manufacturers’ data sheets do not provide guidance concerning the application of stripe coats. Some consider that brushing is most suitable for small complex shapes (such as lattice members and bolted connections), whereas spray application is appropriate for the edge of large structural shapes. Guidance should be obtained from the paint manufacturer, at the specification stage, for suitable methods of application of their material as a stripe coat.

Not all modern paints are capable of being applied by brush. For example, high-build epoxies or urethanes, or quick drying materials such as zinc-rich primers, do not usually lend themselves to brush or roller application, except possibly for small areas of touch-up. This should be checked by consulting the materials data sheet, or the coating manufacturer. Even where application is possible, they will be best applied at a lower film thickness with spray application.

Brushing may not be suitable for paints drying by solvent evaporation such as chlorinated-rubber paints. This is because the solvent evaporates quickly, leaving a very viscous polymer, and to apply the paint satisfactorily requires a low viscosity material which may cause sagging of thicker films. Problems also arise with applying subsequent coats by brush because
the solvent tends to dissolve the previous coat. However, suitably formulated solvent-type paints are produced for brush application.

Generally, brushing is used to apply oleo-resinous types of paint (including long oil alkyds) for which solvents of the white-spirit type are used. Rapidly drying paints, e.g. those drying in under 1 hour, are difficult to apply satisfactorily by brush. Although other types of paint may be applied by brush, special formulations are usually required.

There is little justification for the belief that one should always apply primers by brush. However, for maintenance work where a high quality of surface preparation is not proposed, brush application gives better wetting of rusty and pitted surfaces.

5.1.2 Roller application

This method should not be confused with roller coating application, which is a means of applying paint to flat steel sheet under factory conditions. In the context of painting structural steelwork, it is similar to the method commonly used to apply emulsion paints in domestic situations.

Roller application is particularly suitable for painting large flat areas and does not require the same skill as for spray application. Rollers also allow for application rates up to four times faster than those achieved with brushes. With this method, large trays or containers are used for the paint and the roller is dipped in to transfer the paint to the steel surface. Although useful for rapid covering of large areas, the method does not have the advantages of brush application for priming coats on hand-cleaned steel surfaces, and generally requires the additional use of a brush for edges, corners and other areas not accessible to the roller. In addition, aeration has often been shown to induce small pinpoint voids into roller applied films.

In general, rollers are not recommended for the application of primers or high-build coatings because it is difficult to control film thicknesses with such a method of application. There is also the tendency to ‘roll out’ the coating, i.e. to apply it too thinly, especially with high-opacity coatings containing aluminium pigment. In these cases it is necessary to apply an increased number of coats to obtain the correct film build. Also, with metallic pigmented paints it is necessary to finish off in one direction to avoid showing the path of each rolling.

The size of the roller affects the speed of application; a 230mm × 65mm roller will hold 2½ times as much paint as a 180mm × 30mm roller. Extension handles can help to gain access and reduce scaffolding but it is doubtful whether the practice sometimes seen of a roller fixed to the end of a long pole leads to a uniform paint application or increased speed of application.

The type of roller surface is important. Roller naps of 5mm to 10mm
are best for smooth surfaces and 10mm to 20mm for rough, pitted surfaces. Special rollers are available for pipe coating work. Care must be taken with some modern high-performance coatings since their solvents may attack the adhesive within the roller.

Because of the inherent difficulty in getting even films with brush or roller, it is advisable in the interests of overall practicability to give the contractor some tolerance regarding film thickness. A reasonable figure is that for roller application not more than 10% of the dry film thickness readings may be up to 10% below the specified minimum.

Cleaning is not usually a problem because the roller covers are often discarded at the end of the day’s work. The most commonly used cover materials are mohair, lambswool, nylon and polyester. The material and the length of nap are usually chosen in relation to the paints being applied. The roller itself must be made of a material resistant to the solvents used for particular paints. Special rollers consisting of a series of narrow rolls are often used for application to complex-shaped surfaces and pipes. Although rollers are generally used by dipping the roller into the paint and then applying the paint, mechanised methods are utilised. In these, the paint is supplied from a pressurised tank into the roller head. Other methods such as paint pads or special lambswool gloves or paint mitts are also sometimes used to apply paint. Generally, these methods are more suitable for general coverage rather than for controlled painting. They are useful for painting areas of difficult access and restricted space, e.g. back-to-back angles.

5.1.3 Airspray application

Airspray was the first type of spray equipment developed to provide speedier application of paints, particularly when the quicker-drying types were developed, as these could not easily be applied by brush. With air-spray application, sometimes known as ‘conventional’ spray application, compressed air is used both to atomise the paint and to carry it to the surface to be painted (see Figure 5.1). Paint is fed to the spray gun by one of the following methods.

(i) Gravity feed: the paint is contained in a cup on top of the spray gun and is fed by gravity to the gun nozzle. This action is also helped by a vacuum created at the nozzle by the flow of compressed air. Gravity feed guns are normally used for paints with low or intermediate viscosities, and are very popular for painting small areas because of the ease with which they can be refilled and cleaned. They cannot be used for spraying surfaces overhead.

(ii) Suction feed: the paint is contained in a cup fixed to the underneath
of the gun and is sucked to the paint nozzle by a vacuum obtained with compressed air.

Both gravity feed and suction feed are relatively low speed application methods.

(iii) Pressure feed container: the paint under pressure is supplied to the gun by a displacement pump operated by air pressure. This method is the most efficient for large applications and is particularly effective for applying mastic or coatings containing large or abrasive pigments.

Important considerations in air (conventional) spray painting are:

1. Proper gun distance from the work (150–200mm).
2. Gun should be held perpendicular to the surface to be painted.
3. Paint should be sprayed at the lowest possible atomisation pressure that will adequately atomise the paint.
4. Since it is possible to adjust the controls of the gun to alter the application volume, pattern, etc., the operator should be skilled in its use.
5. Material losses are likely to be 25–50% depending upon numerous factors.
6. The air to the gun should be passed through suitable filters or traps to remove moisture. Airlines to the gun can be extremely moist and this can cause problems with paint materials, particularly urethanes and some types of epoxy.

In recent years, new types of spray gun have been designed specifically for the application of high-solids and water-borne coatings. These are available in pressure-, gravity-, and suction-fed versions.
Equipment for the application of water-borne coatings generally has all-metallic parts that come into contact with the paint, made of stainless steel. Chromium plated steel, bronze or other alloys may cause water-borne coatings to coagulate and, before spraying with equipment that has been used previously for solvent-based coatings, it should be cleaned out with a water-miscible solvent, followed by clean water.

5.1.4 Airless spraying

In conventional air spraying the volume of air required to atomise a given volume of paint is considerable. This arises from the large differences in the specific gravities of air and paint and the requirement to impart high velocity to the paint. This leads to an inbuilt inefficiency in the system because of the large volumes of air needed and the high overspray that occurs with this method. Air spraying can be efficiently used in automatic plants and in properly designed spray booths, but is less efficient for painting a wide variety of structural-steel shapes. Airless spraying is generally more suited to this type of application (see Figure 5.2).

In airless spraying, the paint is forced through a small jet so that it reaches the velocity required for atomisation and, as with a garden hose, a spray of droplets is produced. As there is no expanding compressed air, as in air spraying, to disperse the fluid particles, most of the paint adheres to the work surface, thus eliminating to a great extent spray mist and paint wastage. This results in a faster rate of spraying (up to twice that of air spraying) and less loss of paint by overspray.

The spray gun used looks similar to that used for air spraying, but does not have a compressed-air hose connected. However, the operating parts inside are different. There is a ball valve and seat, a sieve and a tip. The gun is connected by a suitable hose to an air-powered pump which forces the paint to the tip at a pressure some 20–50 times that of the compressed air used to operate the pump. Consequently, although the air pressure is of the same order as that used for air spraying, the actual spray pressure is 12–35 MN/m² (1800–5000 psi).

Very thin fluids such as sealers can be successfully atomised at pressures around 400–800 psi. Most protective coatings require 1500 to 2000 psi while some high-build paints need 2500 psi. Mastics and high-solids materials may have to be applied at pressures up to 5000 psi. The high pressures involved with airless spray present a safety hazard.

Since airless spray does not require compressed air to atomise and deliver the paint, it is not essential for the operation of the airless spray pump, and electric or petrol motors can be used instead. This means that the units can be made extremely portable. Agitators are often built into spray units to ensure adequate mixing during operation. The tip of the gun is made of tungsten carbide to reduce wear from pigments in the paint and...
is an essential element in the control of the process. A range of tip shapes is available for different spray patterns and different types of paint and the paint suppliers’ recommendations must be followed regarding the tip to be employed. Apart from the choice of tip, the only other variables in the process are the paint viscosity and the input pressure. Extension units or ‘pole guns’ may be employed with airless spraying to reduce or avoid scaffolding. These may be up to 3 m in length.

The main advantages of airless spray over airspray are:

(a) Higher output.
(b) Less paint fog, or rebound.
(c) Gives the painter the ability to apply thick films in a single pass.
(d) Coatings often require no thinning before application.
(e) Gives good penetration into pits and crevices due to the high kinetic energy involved.
(f) Extensions can be used to reach some inaccessible areas.
(g) An operator can install the pump and feed at floor level and in dry conditions and work at a height with only a single fluid line.

The main disadvantages are:

(a) Higher purchasing cost.
(b) Greater safety hazard.
(c) Cannot be used for all types of paint.
(d) Cannot be used with pigments with large particle sizes.
(e) Not suitable for fine, decorative finishes, since the spray edges are not sufficiently ‘feathered’.
(f) Since the spraying characteristics, i.e. both volume and spray pattern are fixed with the airless spray tip or nozzle, a selection is required to meet a variety of spraying conditions. Over 90 types of airless spray nozzle are currently available.
(g) Inorganic zinc-rich primers and other highly abrasive paints are not generally suitable for airless spray application.
(h) Frequent clogging of the gun and wear on the orifice causes problems.
(i) It requires a greater distance from the work surface, normally 400–500 mm, than conventional spray.
(j) Although it requires less skill than the use of air spray, it still requires experience and care in handling and regular maintenance of the equipment is important.

5.1.5 Application of plural-component paints by spray

Two-component paints, such as epoxies, have a separate base and curing agent, which are mixed before application. Immediately they are mixed a chemical reaction begins which proceeds over a period of time to produce a solid product. This occurs at ambient temperature and the speed of the reaction is influenced by the nature of the two components. Clearly, once the components have been mixed there is a limit to the time they can be used in the spraying equipment because they will solidify reasonably quickly. Because the final product is soluble only in strong solvents, problems can arise if these materials are not used during the comparatively short period during which application is practicable. This period is called the ‘pot life’ of the paint. To overcome these problems, spraying equipment is available in which the two components are mixed at, or immediately before, the spray gun, so there is no possibility of chemical reaction between the two components in the rest of the equipment (see Figure 5.3). The correct mixing ratios are of paramount importance to achieve the
designed stoichiometric ratio. New equipment features pressure detectors to ensure against 'air bubbles' spoiling this ratio.

The majority of machine mixing systems use reciprocating positive displacement pumps to automatically supply each component at the required ratio. They are then combined in a mix manifold and then a mixer, which as its name implies, thoroughly mixes the base and the curing agent. The mixer uses baffles, whirling impellers or impingement of the fluid streams under pressure, to fold and refold the two components into a homogeneous mixture. Without this key component the two materials would flow through the hose as separate streams and the quality of the final coating would be very poor. The mixed material can then be applied by spray, airless spray, manual or automatic devices, conventional or electrostatic. This method is not suitable for the rapid curing types of urethane, which require mix-at-nozzle, plural spray units.

Of particular interest in recent years has been the airless spray application of heated, plural-component materials. The heating process, for
example the base to 55–65°C and the curing agent 35–45°C, reduces the viscosity and permits the application of very high solids materials, such as solvent-free epoxies polyurea systems or urethanes. Apart from the very rapid application of very thick coatings, these also meet the environmental requirements of reduced solvent emissions. Correctly applied these materials can give very long-term performance, such as with the internal and external coatings on the UK’s Thames Barrier, where such a system has lasted at least twenty-two years and, apart from some mechanical damage with ship collisions, is still in excellent condition.

The obvious difficulty with all dual-component equipment is that it is more complicated than single feed units. Because of its high output, any malfunctioning or operator error can result in a large area of defective coating that is inevitably both difficult and costly to rectify. All operators of such equipment, regardless of how experienced they are with normal airless spray application, should have special training.

### 5.1.6 Electrostatic spray

This method is suitable for spraying either liquid or powder coatings. Unlike other spraying processes, it has the ability to paint all parts of an object from a fixed position, e.g. the whole of a pipe can be coated without moving the spray from the front of the pipe to the back (see Figure 5.4). This is achieved by passing paint droplets through a powerful electrostatic field, during which they receive a high charge, typically up to 75kV for

![Figure 5.4 Details of electrostatic spray gun.](image.png)
hand-held guns and up to 180 kV for some automatic equipment and so become attracted to the item to be coated, which is earthed.

This method is widely used for tubular goods, e.g. pipes, garden furniture, bicycle frames and wire fences. Electrostatic spray painting is generally more economical than other types. It is universally used for the factory application of fusion-bonded epoxy powder coatings to the external surfaces of pipelines. The method is not used for the painting of general constructional steelwork, but on sites it is well suited for open steel work such as gratings or railings.

The advantages of electrostatic spraying include:

(a) It can give a fairly complete overall coverage simultaneously to both back and front of small sections of simple shape.
(b) There is less spray loss than with other methods of application, typically by 50–75% compared with air spray.
(c) It gives a uniform film thickness and edges and corners are well coated.
(d) It is quicker than conventional spraying techniques and, when operated in works, no complex exhaust systems or paint Booths are required.

Its disadvantages include:

(a) Only comparatively thin coatings can be applied.
(b) It can only be used on the bare, conductive substrates.
(c) Generally, only one coat can be applied by this method since the applied coating insulates the surface.
(d) The paint or powder has to be specifically formulated for the purpose.
(e) Paints containing conductive pigments, for example zinc-rich primers, cannot be used.
(f) The high voltages used present a safety hazard.
(g) The equipment is more expensive and more cumbersome to use than a normal spray gun.
(h) It is not possible to spray into some crevices or internal surfaces due to the Faraday Cage effect.

5.1.7 Other application methods

Most structural steelwork is painted by one of the methods discussed above. However, other application methods are also used to a limited extent and these will be briefly discussed in this section.
5.1.7.1 Dipping

Application by dipping is sometimes carried out for small fabrications difficult to paint by other methods; pipes are also coated by dipping. The method is basically simple. Either the steel is dipped into a tank containing paint or, sometimes, the tank is raised to cover the stationary steelwork. Paints have to be specially formulated and suitably thinned for the dipping method. Owing to the large exposed surface of the paint, excessive evaporation of solvent can occur and the viscosity must be regularly monitored and corrected with addition of more solvent. The whole process is generally less easily controlled than the other methods and is not suited to all types of paint. Clearly, there is a limitation on the size of steelwork that can be treated in this way, partly because of the size of the tank and partly because of the amount of handling required. Provided the design of the process allows for flow of the paint to all parts, internal and external surfaces can be coated in one operation. The method is rapid and skilled operators are not required. However, ‘drips’ and ‘tears’ tend to occur on the lower parts of the painted steelwork and there is a tendency for edges to be coated to a lower thickness than the main surfaces.

This method is widely used for comparatively small fabrications, particularly where final stoving is carried out and where the process can be automated. However, it is not generally used for structural steelwork, because it is not suited to many of the paints commonly used for such structures and the shear bulk of the steelwork would make handling difficult.

5.1.7.2 Flow coating

As a variation of the dipping process, items on-site are occasionally flow coated. This consists of building a watertight reservoir, generally in plastic around the base of the item to be coated, and pumping the paint through a hose to the top of the item. It is most useful for complicated structures such as transformer radiator tanks where an operator directs the hose from a point above so that the paint covers the inner surfaces. The only alternative to reach such surfaces is by spray nozzles on the end of extension tubes and in most such cases the spray operator has to work ‘blind’. Such a process still requires the cleaning and preparation of the surface before painting, and if this cannot be achieved by solvent or steam washing, the paint application is unlikely to achieve its object.

If flow coating is carried out the paint must be carefully selected for its purpose, and during the flow coating operation the paint viscosity must be checked and rectified at frequent intervals.
5.1.7.3 Miscellaneous methods

Methods such as trowelling on thick coatings of high viscosity are sometimes used. Barrelling, similar to the method used for sherardising zinc coatings, is also used for small components. Other methods widely used for industrial painting such as roller coating and curtain coating are not used for structural steelwork.

5.1.8 Comparison of application methods

The main comparison between the four common methods of application must be on the speed of operation. The following figures indicate the average area of steelwork that an operator might be expected to cover with one coat of paint per day: brush, 100 m²; roller, 200–400 m²; airspray, 400–800 m²; and airless spray, 800–1200 m².

The rate of application is not the only matter to be taken into account, but the advantages to be gained by spraying are clearly demonstrated. Brush application is the slowest but for many situations the most effective, and masking and loss of paint by overspray are avoided. Roller coating is generally limited to large flat surfaces, although special rollers have been developed for other shapes. Spraying is the fastest method and in most situations airless spray is preferred.

5.2 Application conditions

Only paint application will be considered here; surface preparation is considered in Chapter 3.

To obtain a satisfactory job with all methods of coating application the following are important:

1. There is access by an unrestricted, safe, working platform.
2. A cleaning team is ahead of the applicators. This particularly applies to airless spray, which pumps out a large volume of paint so that there is a tendency for applicators to spray everything in the path of the spray gun. Most experienced painting inspectors can recall such items as mud, piles of abrasive, cigarette packets, broken light bulbs, etc., that have all received a coat of paint in lieu of the substrate.
3. Correct lighting so that the operative can move about safely and have sufficient light on the work surface to carry out the job correctly. This is particularly important for high-build coatings, such as coal-tar epoxies where succeeding coats are of the same or very similar colour.
4. For spray operators on large work there should be a paint loader to keep up with the sprayers’ output.
5 With spray operation it is preferable to have another operator to follow up the sprayer and touch-in and remedy visual defects.

5.2.1 Pre- or post-fabrication

For new structural steelwork there are four main procedures for carrying out the coating operations:

1 Surface preparation and priming at the fabricators. Coating system completed on site after erection.
2 Surface preparation and priming, plus the main part of the coating system completed at fabricators. Damage repaired and final coat only applied on site after erection.
3 Surface preparation, priming and coating on the ground at site and before erection.
4 Surface preparation, priming and coating at site and after erection.

Obviously there are further variations possible but one of the above is normally the main choice. It is not possible to state that any one method is preferable, there are advantages and disadvantages to each one. A NACE publication\(^2\) comprehensively sets out the factors that have to be considered. Briefly the choice depends upon, amongst other factors:

1 The size and complexity of the fabrication.
2 The extent to which welding has to be completed after surface preparation and priming.
3 Availability of facilities at the fabricators, such as, convenience of access to items on the ground, adequate and suitable storage, etc.
4 Access on site.
5 Type of coating materials to be used, e.g. quick-drying, stacking resistance, etc.
6 Ambient conditions on site.

Pre-fabrication surface preparation and priming is generally the most economic option. In such cases, the user is seldom able to specify the paint manufacturer to be used since it is not practicable for the fabricator to change materials frequently. Ideally, specially formulated primers should be used, such as those based on polyamide-cured epoxy and pigmented with zinc phosphate. These dry rapidly and can be overcoated with most other types of paint for periods up to at least one year, without the need for special preparation other than the removal of dirt and repair of damage. The addition of fine-grade micaceous pigment to such primers also has advantages since it can provide a matt surface that aids overcoatability.
If primers are to be on the surface during welding operations, it is important that they should have two, quite separate, certificates of approval: (i) to indicate a satisfactory level of toxicity during the welding operation and (ii) to confirm that it will not adversely affect the strength of the weld. The latter is dependent upon paint film thickness and manufacturers’ recommendations to this effect should be followed. If the area to be welded is relatively large, then preparation and priming after fabrication may well be the most efficient and economical option.

In almost all cases there are considerable advantages in stripe coating, that is, applying an extra coat of primer along edges, welds, etc. This is not popular with many painters because of the amount of effort involved for such a relatively small area of coverage. It must also add to the cost of application but for the end-user there is ample economic justification in increased durability. Paint systems commonly fail first at edges, welds, etc. because of the reduced paint thickness. T.N.O. Paint Research Institute in the Netherlands has studied the rheology of coatings applied to edges and has found that for normal, solvent-based paint systems there is a reduction of 40–70% of film thickness compared with the adjacent flat surfaces.3

5.2.2 The painting shop

The layout, equipment and environmental controls are important factors in determining both the efficiency of the painting process and the standard of the coating, i.e. its overall durability. Generally, insufficient attention is paid to the ability of a fabricator to achieve the necessary standards required and specified. It may well be advantageous to carry out a check or audit of the works before contracting the painting of steelwork. Apart from surface preparation, which is now capable of fairly strict controls, poor painting procedures are the most likely causes of inadequate coating performance. Against the obvious advantages of shop-controlled work must be weighed the occasional situation where numerous small, loose and separate items have to be painted, or where access has to be obtained to all faces of a large fabricated structure close to, or on, the ground.

Requirements such as cranes suitable for handling the steelwork, sufficient weatherproof area to paint and store the steelwork, properly maintained equipment for painting, sufficient trained operators and a proper division between blast-cleaning and painting operations are very important and should be checked. However, the particular factors that affect paint application are those concerned with environmental control, temperature and lighting, and these will be considered in this section. These will often be considered for health and safety reasons rather than for purely technical ones. Nevertheless, these environmental factors do
influence the efficiency of paint application and should be properly controlled.

5.2.3 Ambient conditions

Although it would seem obvious that site painting should be scheduled for the most favourable months of the year, in practice it is a common experience to observe paint being applied under virtually any weather conditions, short of heavy rainfall. Even with the latter it is also a common experience to see work re-start immediately after the rain has stopped and when the surfaces are still, at least, damp. This is perhaps not surprising in countries like the UK with unpredictable summers. McKelvie\textsuperscript{4} has produced evidence on the influence of weather conditions in the UK. This shows that the period of December and January cannot be expected to be favourable for outdoor painting unless special precautions such as enclosure, heating and/or special paint systems are used. February is also generally unsatisfactory and November and March to a lesser extent. The months of May and June provide the best conditions with a greater likelihood of efficient use of working time, when the painting is started later in the day. The work applied to London, Manchester and the Cardiff area; further north, for example in the Shetland Isles, the ‘weather window’ is generally even shorter and in some years ideal conditions have been non-existent. It is more important in these circumstances to select paint systems on the basis of their tolerance to application conditions rather than standard systems that really only give high performance under close to ideal application conditions.

5.2.3.1 Temperature

Temperature influences coating application in a number of ways, e.g. drying time, curing time of two-pack materials, solvent evaporation and paint viscosity. Temperature has a marked effect on the viscosity of paints; the actual effect depends on the paint but a typical gloss paint may become twice as viscous when temperatures drop from 30 to 20°C. The temperature at which paint is stored is also important. Depending on the type of paint and temperature, it may be necessary to warm or cool the paint before use.

Two-pack materials which cure by chemical reaction are extremely sensitive to temperature. Low temperatures will slow the reaction and high temperatures will cause it to accelerate.

Most epoxies will not cure below 5°C and ideally should be applied to surfaces above 10°C. Any paints applied to a cold surface will instantaneously cool to the temperature of the substrate and this will impair the
flow into the innumerable interstices and crevices of, for example, a blast-cleaned surface.

Conversely, at high temperatures, the viscosity of any type of paint will drop, possibly to the point where it will have undesirable rheological characteristics such as runs and sags on vertical surfaces.

In extremes of temperature, brush and roller application may require the addition of extra solvent, with consequent loss of film thickness. Spray operation, both air or airless, will also need modification to spraying pressures, tip sizes and possibly the use of special solvent to avoid dry spray and other film defects.

Temperature is also critical for the application of water-borne coatings since there is a minimum temperature at which a proper film will form by coalescence.

Many paint manufacturers only provide data about their products, such as two-pack epoxies, at standard temperatures of 20 or 23°C, whereas variations from the standard can make significant practical differences to such properties as pot life, minimum and maximum allowable overcoating periods, and drying and curing times. Very approximately, a difference of 10°C can double or halve the time, as appropriate. The effect varies with the quantity of solvent present, the type of curing agent and mass of paint. This should be checked for each type and make of paint used. Apart from their effect on paints, low temperatures may lead to moisture condensation on cold steel surfaces. This can lead to problems with paint application. When temperatures have to be raised, only indirect heating methods should be used. Heaters that produce combustion products inside the shop should be avoided. In situations where it is impracticable to heat the whole shop, local heating in the working area may be employed. Where the steel surface has to be heated, this must be carried out cautiously to avoid contamination or overheating of the steel itself.

The outer surface of a paint film should never be force heated in order to speed drying. This is because with most materials, particularly two-pack, that cure by chemical reaction, this will cause the top surface of the paint to cure and leave the underlying paint film uncured: this can occur in hot sunlight on a newly applied paint and the effect is magnified with black or dark-coloured coatings.

5.2.3.2 Relative humidity

The moisture content of the air has an influence on painting operations and is indicated by the relative humidity at a particular temperature. Relative humidity is important during paint application for two reasons. Firstly, depending on the amount of moisture in the air and the temperature of the steel surface, some condensation may occur on the steel and this may lead to adhesion problems with some paints. Secondly, some paints are
sensitive to humidity during their curing, regardless of whether condensation occurs or not.

It is normal practice to specify that paints shall not be applied to surfaces that are within 3°C of the dewpoint. The higher the relative humidity, the greater the risk of condensation, for example, in the temperature range 0–10°C, if the RH is 80% the temperature needs to drop 4 degrees before condensation occurs, but at 98% RH it only needs to drop a half a degree. Therefore, if the RH is 85% or higher, painting operations should be critically reviewed since the dewpoint is only 1 or 2°C away at the most. These degrees of cooling may be reached during application solely by solvent evaporation effect, particularly when there is rapid evaporation of solvents, such as with low-boiling types with high evaporation rates. Fast evaporation of solvents can, therefore, reduce the temperature of the paint droplets below the dew point during the application. When this occurs, moisture from the atmosphere condenses on the surface of the paint particles and is then entrapped in the paint film. This may prevent proper film formation.

An important factor is the trend of humidity conditions. If weather conditions can confidently be expected to remain static or improve in, say, the following 6 hours, then application could start when the surface to be painted is less than 3°C above dewpoint.

Some paint systems, such as moisture-cured urethanes and zinc silicate primers, require a degree of moisture before they will cure, but most high-performance coatings are adversely affected by moisture during application and curing.

The relative humidity conditions applicable to various coatings should be but are not always, given in the paint manufacturer’s data sheets. Water-borne coatings are particularly sensitive to conditions of high relative humidity. The moisture in the coating film will evaporate more slowly and increase the time the coating remains water sensitive, i.e. can be damaged or even washed off the surface by rain or condensation. Prolonged exposure of a wet coating on a bare steel substrate can also cause flash rusting.

5.2.3.3 Ventilation

Ventilation is necessary in a paint shop or confined space to keep the concentration of fumes and vapours to an acceptable level. This requirement is determined by the threshold limit value (TLV) for solvents. This is the total, in parts per million, of the solvent which over an 8-hour day will give no ill-effects. Tables providing this information have been prepared and for some solvents, including most ketones, it is low, e.g. 50–100 ppm. Generally, in modern painting shops overspray is collected using either down-draught ventilation near where the painting is carried out or by using spray arrestors. However, ventilation is also required in other parts
of the shop to reduce the possibilities of explosion of low-flash-point solvent and also to reduce the amount of dust and contamination in the shop.

5.2.3.4 Lighting

Adequate lighting might appear to be a fairly obvious requirement, but in some paint shops and under some site conditions, the amount of light is in fact inadequate for proper painting of the steel and effective inspection of the applied paint coating. The intensity will be determined by the type of work but generally requires to be between 500 and 1000 lux.

5.2.3.5 Wind and weather

Exposure of surfaces before paint application or of uncured paint films to rain, frost or dew will generally have a damaging affect both on the inherent adhesion and on the ultimate durability.

Painting in high winds should be avoided, especially when spraying as, apart from risk of overspray, the wind blowing across the atomised paint can result in a powdery, porous, dry-sprayed film. High winds also increase the possibility of dirt, sand, debris, etc. falling on the cleaned surface of the wet paint.

5.2.4 Storage of paint

Paint must be stored in proper store rooms under proper temperature control with adequate fire precautions and should be open only to authorised personnel. All paint and solvent containers should be clearly marked and recorded in a book so that stock is used in the correct order. If the shelf life is exceeded, then the particular paints should be disposed of or, depending on the contract terms, returned to the supplier.

5.2.5 Preparation of paint before use

Even where paints are properly stored, it is necessary to prepare them correctly before use. Pigments tend to settle during storage so thorough mixing is required to ensure homogeneity. This is particularly important with heavy pigments, e.g. in zinc-rich paints. If these are not thoroughly mixed, the dry film may not meet the requirements of the specification. Before mixing, the paint should be brought to the approximate temperature of use. Mixing is usually carried out mechanically in special equipment by means of revolving stirrers. Alternatively, up to about 20-litre cans can be prepared by shaking in suitable units. If manual mixing is to be
carried out, this should not be attempted with larger containers of paint; a can size of about 10 litres is the maximum that can be mixed in this way. Two-component paints, e.g. epoxies, must be mixed carefully. The ‘hardener’ should be added in the correct ratio as specified by the paint manufacturer. Two-pack materials should only be used in the complete ‘pack’ size. Attempts to use fractions inevitably lead to incorrect proportions. Apart from the inaccuracies in measurement, there is also the difficulty of making an allowance for the amount of viscous material left on the sides of the measuring container.

The pack size should always be chosen in order to allow for application within the ‘pot life’ of the paint. Thinning of paint before and during application must be carried out in accordance with the paint manufacturer’s recommendations. Only thinners of the recommended type must be used and should be added to a well-mixed paint. If, after mixing, there is any skin or contamination of the paint, then it should be strained to remove all foreign particles. It is probably necessary to strain all paints that have been used and left standing for some time.

5.3 The painter

Paradoxically, in many countries, including the UK, a house painter and decorator is more likely to be trained and experienced in the methods of paint application than an industrial painter working on a major industrial project. To rectify this the National Association of Corrosion Engineers (NACE) in the USA is starting a painters’ qualification programme. Painters will be required to demonstrate their skill in or knowledge of safety regulations, degreasing, surface preparation of both steel and concrete, methods of application and use of quality control instruments such as wet film thickness gauges (see Figure 5.5), dry film thickness gauges and wet sponge holiday detectors.

It is to be hoped that other countries will follow this excellent lead. However, in the past, painting contractors have been reluctant to finance such schemes because of the transient nature of the employment. Such ideas can only work if the end-user insists on, and pays a premium for, qualified painters and also makes allowance for the interim period at the start of the scheme. Fortunately, in many countries, including the UK and the USA, there are schemes being implemented for the pre-qualification or approval under a quality assurance scheme of painting contractors. This may well redress this deficiency.

5.4 Paint manufacturers’ data sheets

Data sheets produced by the paint manufacturers provide the major source of information concerning their materials. Very often compliance
with the manufacturer’s data sheet forms part of the requirements of the contract. Disregarding these recommendations could relieve the paint manufacturer of any responsibility in the event of subsequent problems. It is essential to possess the latest version of the relevant data sheets which are available to both painters and quality control inspectors.

Of necessity, a paint material has to be a compromise of properties, some of which are in direct conflict with each other. Unfortunately, paint manufacturers are reluctant to mention any aspect that requires special care and attention in case it implies a weakness in their own proprietary material rather than an inherent weakness of the particular type of paint. The following information is the minimum required:

(a) General descriptive name and colour.
(b) Principal characteristics and recommended uses.
(c) General description of binder and, if appropriate, main pigmentation.
(d) Any special requirements in application and use.
(e) Mass density.
(f) Solids content by volume and tolerance allowable.
(g) Recommended dry film thickness with a minimum and maximum permitted.
(h) Touch-dry time.
(i) Minimum safe period for the stacking of painted articles.
(j) Minimum interval before overcoating.
(k) Maximum interval before overcoating.
(l) Full cure.
(m) Pot life, if applicable.
(n) Properties (h)–(m), as above, at a range of temperatures.
(o) Shelf life and recommended storage conditions.
(p) Recommended methods of application.
(q) If appropriate, precautions necessary for any particular form of application.
(r) Recommendations for suitable spray set-ups, where appropriate.
(s) Recommended thinners.
(t) Cleaning solvent required.
(u) Compatibility with primers or topcoats, as applicable.
(v) Mixing instructions.
(w) Induction time, if applicable.
(x) Safety precautions. For most modern paint systems there should be separate data sheets on safety requirements giving full details of threshold level values and lower explosive limits and any other hazards applicable.

5.5 Health and safety matters

5.5.1 Airless spray

The pressures involved in airless spray may be up to 6000 psi. There are obvious dangers of handling equipment at such pressures. The fluid hose and fittings must be kept in good condition and replaced if there are any signs of damage. The material from which the hose is made must be fully resistant to solvents and suitably earthed to prevent a build-up of static electricity. All hose connections should be tightened securely and checked before use. The airless spray gun should be fitted with a safety catch to prevent accidental operation of the trigger and fitted with safety ‘horns’ or ‘tips’ that protrude in front of the orifice. These are often coloured yellow and their purpose is to prevent anyone getting part of their body too close to the orifice. With such high pressures forcing material through a small
orifice there is a danger that paint could be injected into the skin, resulting in a loss of a limb or even a fatality.

5.5.2 Paint materials

5.5.2.1 General

The solvents, resins, pigments and other ingredients in paint coatings can all affect health by inhalation, ingestion and absorption in the body. Some possible hazards are highlighted below but they do not represent all that might occur. It is essential that a paint manufacturers’ Material Safety Data Sheet (MSDS) or, in some cases, the Technical Department of the paint manufacturer, is consulted before using any specific material, or if in doubt about any risk or safety phrases on the label of the containers.

5.5.2.2 Flammability

All coatings that contain organic solvents are flammable and so also may be the resins. The greatest danger lies in application when coatings in the liquid state are present.

5.5.2.3 Explosive hazard

Most coatings are not explosive in the liquid state. Even if the surface of the liquid is alight it will not explode. However, in a fire the paint container can expand and the lid can be blown off the container owing to expansion. In that case flammable material could be spread over a wider area.

In an enclosed space or stagnant pocket, the possibility of explosion depends upon the concentration of solvent vapours in the atmosphere. With very high concentrations, no explosion can occur because there will be insufficient oxygen. In low concentrations there may be insufficient solvent vapour present to ignite and explode. Painters are only concerned with this lower explosive limit (LEL). Table 5.1 gives typical LEL figures by volume in air for common solvents. Table 5.2 gives typical LEL figures for different types of paint.

Adequate ventilation is the key requirement for painting in confined spaces, but even with adequate ventilation there are other necessary precautions:

(i) No smoking, welding or flame cutting within at least 15 m from the painting operation.

(ii) All electrical equipment should be explosion-proof and no commutator-type electric motors should be used in the vicinity.

© 2002 D. A. Bayliss and D. H. Deacon
(iii) All tools, equipment, footwear, etc. should be of the type that does not generate sparks.
(iv) Nylon overalls or other plastic items liable to cause static discharge should not be worn.
(v) Equipment liable to generate static electricity, such as blast or paint spray hoses, should be adequately earthed.
(vi) Solvents or paints should not be applied to hot surfaces.

5.5.2.4 Flash point

The flash point is the temperature of a solvent at which it releases sufficient vapour to ignite in the presence of a flame. In this respect, the higher the flash point, the safer the solvent. The closed-cup method of flash point determination gives lower results than the open-cup method and is therefore normally the figure quoted. Table 5.1 gives typical closed-cup flash points for common solvents.

5.5.2.5 Evaporation rate

The relative evaporation rate for a solvent is based on an arbitrary value of 1 for ethyl ether. The higher the evaporation rate the longer it will take for the solvent to evaporate from the paint film and form solvent vapour in the atmosphere. However, the slow evaporation means that the paint film stays wet longer and presents a greater flammability hazard. Table 5.1 gives the relative evaporation rates for common solvents.

5.5.2.6 Solvent vapour density

The greater the solvent density, the more likely that the vapours will accumulate in the lower portions of a confined space. Localised pockets may

<table>
<thead>
<tr>
<th>Solvent</th>
<th>Evaporation relative rate</th>
<th>Closed-cup flash point, °C</th>
<th>LEL vol % in air</th>
<th>TLV (ppm in air)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone</td>
<td>4</td>
<td>32</td>
<td>2.15</td>
<td>230 1000</td>
</tr>
<tr>
<td>Ethyl alcohol</td>
<td>20</td>
<td>14</td>
<td>2.23</td>
<td>1000 —</td>
</tr>
<tr>
<td>Methyl ethyl ketone</td>
<td>8</td>
<td>1</td>
<td>1.81</td>
<td>200 300</td>
</tr>
<tr>
<td>(MEK)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White spirit</td>
<td>150</td>
<td>38–43</td>
<td>1.10</td>
<td>100 —</td>
</tr>
<tr>
<td>Naphtha</td>
<td>105</td>
<td>38–43</td>
<td>1.20</td>
<td>300 400</td>
</tr>
<tr>
<td>Toluene</td>
<td>15</td>
<td>4</td>
<td>1.27</td>
<td>100 150</td>
</tr>
<tr>
<td>Xylene</td>
<td>35</td>
<td>16</td>
<td>1.00</td>
<td>100 150</td>
</tr>
</tbody>
</table>

Table 5.1 Solvent properties
then reach the lower explosive limit even though the bulk of the volume is satisfactory.

5.5.2.7 Reactivity

Many of the two-pack, chemically cured coatings, such as polyesters, epoxies and urethanes, and particularly those with 100% solids, generate a substantial heat if left in the container for a long period after the curing agent has been added. For example, if left overnight the exothermic reaction could build up to a flammable level.

5.5.2.8 Hazards from solid components of paint

Many high-performance coatings can cause dermatitis. Epoxies containing solvents are particularly hazardous, since they can penetrate the skin more easily. The effect appears to be cumulative in that once a person is sensitised, even limited contact can cause a reaction all over the body. The use of protective ointments and creams is a worthwhile precaution. Coatings may contain metals or metallic compounds; cobalt can cause pneumonia and asthma; chromium can irritate or damage the nose, lungs, stomach and intestines and can increase the risk of cancer; arsenic can increase the risk of cancer; zinc chromate increases the risk of cancer and has been banned in many European countries. Isocyanates are used in urethane coatings. If present as free monomeric isocyanates they can result in chest tightness, vomiting, abdominal pain and redness, swelling and blistering of the skin. Chronic exposure may result in flu-like symptoms such as fever, chills, aching and nausea with reduced lung function and possible lung damage. Once workers are sensitised, even exposure to airborne quantities below the occupational exposure limits may result in serious asthmatic reaction.

Epoxy resins and curing agents are used in both water- and solvent-borne coatings. Materials such as glycidyl ethers are used to modify the resins and these are irritants to the respiratory tract as well as the eyes and skin. Aliphatic polyamines are sometimes used as curing agents for these plural component materials and are strong irritants and sensitisers.

Coatings may contain forms of crystalline silica. Types that may be listed in a safety data sheet include: quartz, cristobalite and trydimite. The dry dust from these could cause silicosis.

5.5.2.9 Solvent hazard

Overexposure to solvents can lead to severe health problems. Typical solvents found in industrial paint systems and their possible effect on health are as follows:
Ketones: for example, methyl ethyl ketone (butan-2-one or MEK) and methyl isobutyl ketone (4-methylpentan-2-one or MIBK) can cause irritation to the eyes, nose and throat. In high concentrations, exposure can result in narcosis, with symptoms of headache, nausea, light-headedness, vomiting, dizziness, loss of coordination and loss of consciousness; prolonged exposure can be fatal.

Aromatic hydrocarbons: for example, toluene, xylene, dimethyl benzene and other solvents similar in structure to benzene. Contact with these solvents can cause skin irritation, but the respiratory problems are severe. Acute exposure can result in narcosis or can damage the lungs. Chronic exposure can damage the liver, kidneys and bone marrow. High concentrations can be fatal.

Alcohols: for example, methyl alcohol (methanol) may be reported as toxic and other alcohols tend to irritate the skin, eyes and respiratory system. Acute exposure can result in depression of the nervous system, thus slowing the activity of the brain and the spinal cord. A sufficiently high exposure can be fatal.

5.5.2.10 Injury by penetration into the skin

Solvents or solvent vapours that enter the pores of the skin will give symptoms similar to those of solvent inhalation. Skin contact with solvents should be avoided wherever possible.

5.5.2.11 Injury by swallowing

Solvents that remain as liquid in the stomach should be rendered harmless by being metabolised. However, lung irritations can occur because much of the dose will leave the body as vapour in the expired air. Fortunately, a frequent result of swallowing solvent is the protective reflex of vomiting.

5.5.2.12 Eye injury

Solvents in the eye can cause corneal necrosis. Afflicted eyes should be flushed with water and medical attention should be obtained at once.

5.5.2.13 Toxicity

The maximum allowable concentrations of solvent vapours are known as threshold limit values (TLV) and can be listed in two forms: TLV-TWA (time-weighted average) and TLV-STEL (short-term exposure limit); the latter is more commonly quoted in North America than in Europe. The definition of TWA is the time-weighted average concentration for a
normal 8-hour workday and a 40-hour work week, to which nearly all workers may be repeatedly exposed, day after day without adverse effect. STEL is the maximum concentration to which workers can be exposed for a period up to 15 minutes continuously without suffering from: irritation to the lungs; chronic or irreversible tissue changes; or narcosis of sufficient degree to increase accident-proneness, impair self-rescue or materially reduce work efficiency; provided that no more than four exposures per day are permitted and provided that the TLV-TWA is also not exceeded.

Ventilation is the key to safe application of coatings in enclosed areas. Its significance cannot be overemphasised from the standpoint of fire, explosion and health. Suction fans should always be used and positioned so that they draw from the lower areas of the enclosed space. Ventilation should be continued until the coating is sufficiently dry to ensure that, with the ventilation removed, no area of the tank will build up vapours to the explosive limit.

The minimum ventilation air in cubic metres per minute may be calculated from the formula:

\[
\frac{(P \times A) + (Q \times B)}{t}
\]

where \(P\) = volume of paint applied in litres in time \(t\); \(Q\) = volume of added solvent used in the paint applied in time \(t\); \(A\) = ventilation air quantity for 1 litre of paint to reach 10% LEL (obtain this information from paint supplier); \(B\) = ventilation air quantity for 1 litre of solvent to reach 10% LEL (obtain this information from paint supplier); \(t\) = time of application in minutes, of volume \(P\) of paint.

**Example**

100 litres of paint \((P)\) plus 5 litres of thinner \((Q)\) are used within 45 minutes \((t)\). \(A = 60\, \text{m}^3\), \(B = 130\, \text{m}^3\).

Ventilation air quantity to reach 10% LEL is then

\[
\frac{(100 \times 60) + (5 \times 130)}{45} = 147.7\, \text{m}^3/\text{min}
\]

Table 5.1 gives the TLV-TWA and TLV-STEL for common solvents. Table 5.2 gives the TLV-TWA and TLV-STEL for common paints. Solvent vapour meters which monitor toxic or combustible gas levels should always be used for the application of coatings in enclosed areas. Visitors and workers in such areas should wear air-fed masks.

Today, there is particular concern about the spraying of paints containing isocyanates, for example urethanes, isocyanate-cured epoxies, etc. Their wide use is due to their considerable weather-resistant and
### Table 5.2 Coating properties

<table>
<thead>
<tr>
<th>Coating</th>
<th>Flammability</th>
<th>Solvent</th>
<th>LEL vol. % in air</th>
<th>TLV-TWA (ppm)</th>
<th>Toxicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil-based Flammable</td>
<td>Flammable</td>
<td>Aliphatic hydrocarbon</td>
<td>0.8 if contains</td>
<td>100 if turpentine; 500 if white spirit</td>
<td>Non-toxic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>may contain turpentine</td>
<td>1.1 if white spirit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alkyd Flammable</td>
<td>Flammable</td>
<td>Aliphatic or aromatic petroleum</td>
<td>1.1</td>
<td>200–500</td>
<td>Non-irritating</td>
</tr>
<tr>
<td>Chlorinated rubber</td>
<td>Non-flammable</td>
<td>Aromatics</td>
<td>1–1.3</td>
<td>100</td>
<td>Possible skin irritation due to solvent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Non-toxic</td>
</tr>
<tr>
<td>Vinyls Self-extinguishing</td>
<td>Ketones and aromatics</td>
<td>1.3–1.8</td>
<td>100</td>
<td>Non-toxic</td>
<td></td>
</tr>
<tr>
<td>Epoxies, solvent-based</td>
<td>Ketones and aromatics</td>
<td>1.3–1.8</td>
<td>100</td>
<td>Dermatitis</td>
<td></td>
</tr>
<tr>
<td>Coal-tar epoxy</td>
<td>Will support combustion</td>
<td>Ketones and aromatics</td>
<td>1.3–1.8</td>
<td>100</td>
<td>Fumes irritating Skin irritation Dermatitis Toxic fumes Dermatitis Severe skin irritation Possible mild skin irritation</td>
</tr>
<tr>
<td>Polyurethane Flammable</td>
<td>Ketones and aromatics</td>
<td>1–1.3</td>
<td>100</td>
<td>Non-toxic</td>
<td></td>
</tr>
<tr>
<td>Coal-tar Flammable</td>
<td>Aromatics</td>
<td>1.1–1.27</td>
<td>200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inorganic zinc silicate</td>
<td>Non-flammable</td>
<td>Ethyl alcohol</td>
<td>3.2</td>
<td>1000</td>
<td>Possible mild skin irritation</td>
</tr>
</tbody>
</table>
abrasion-resistant properties. Their use by operators possibly unfamiliar with the health hazards has prompted the UK Health and Safety Executive to produce a guidance leaflet for the motor repair trade.6

5.5.2.14 Instrumentation

The percentage of solvent vapour present in a confined atmosphere can be determined by the use of an apparatus that draws a sample of the air through a calibrated tube containing a chemical reagent. The chemical in each type of tube is sensitive to a particular gas and changes colour appropriately. Advice should be obtained from the paint manufacturers as to which type of tube is the most suitable for their product. Although the method is not suitable for continuous sampling, its cheapness and ease of use make it suitable for applications where accuracy is not of prime importance.

Solvent vapour meters are also available that can detect toxic or flammable gases or oxygen deficiency either continuously or as a portable instrument. Such instruments generally work by the use of a semiconductor metal oxide detector. Semiconductor devices (for example, transistors) depend upon the modification of their electrical conductivity properties by the addition of certain chemical impurities, known as doping. When metal oxides are ‘doped’ with small concentrations of suitable metals or rare earths, they can be made to function as gas detectors. The semiconductor element of such detectors consists of a small pellet of ‘doped’ oxide which is heated by a minute platinum/rhodium filament. When a flammable gas passes over the pellet, the gas is adsorbed by the oxide surface and alters the electrical conductivity. This change in conductivity produces a small voltage which, after amplification is recorded on a meter. These instruments can be very sensitive and selective and can measure low concentrations. It is reported, however,7 that some makes of instrument on the world market lack selectivity in that they will respond equally well to a number of gases with different explosive ranges. This may produce misleading and possibly dangerous readings if the user is unaware that the gas sampled is not that for which the instrument is calibrated.

The instruments also measure the oxygen content of the atmosphere by the use of a galvanic cell which produces current in proportion to the oxygen content. When the current reads a pre-set level, an alarm sounds.

5.5.2.15 Water-borne coatings

It is commonly thought that application of water-borne coatings eliminates all the hazards associated with the application of solvent-borne coatings. It
is certainly true that they present much less risk of fire and explosion since they have a much higher flash point. It is however important to remember that most water-borne coatings, and this especially applies to the water-reducible types (see 4.9.5), contain some organic solvent, and so personal safety precautions are still important and often necessary. For instance, dizziness, watery eyes or headaches while applying water-borne coatings may indicate inadequate ventilation in the work space and the need for a respirator. This is particularly the case when water-reducible types are being spray applied. It may not be necessary with brush or roller application but much depends upon the degree of ventilation.

The amount of solvent in a water-borne coating should be determined from the Materials Safety Data Sheet (MSDS) and this should be consulted to determine the degree of protection required for any particular product.

Different people have different sensitivities to materials and some people are more sensitive to water-borne coatings than others. The use of gloves and/or protective cream is always an important safeguard.

5.5.2.16 Polyurea spray coatings

Because they have no VOC’s and other advantages over their traditional counterparts, such as polyurethane, the relatively new polyurea elastomer coatings are now increasingly used for pipelines, tank interiors etc. The potential health and safety hazards associated with the handling and spraying of polyurea arise both from the toxicological properties of the chemical components and the mechanical aspects of the dual-component spray application necessary for these fast curing, high-build materials.

Under normal equipment operating conditions, the isocyanate component and the resin component react instantaneously so that there is not an excess of either unreacted isocyanate or amine at the spray nozzle. However, even under ideal operating conditions, very small amounts may be present as an aerosol or vapour. These can cause irritation to the eyes and respiratory tract. Repeated inhalation of such an aerosol or vapour may produce a hypersensitivity reaction of the respiratory tract similar to an asthma-like response. Contact with the skin can also cause similar irritation and a hypersensitivity reaction.

**References**


© 2002 D. A. Bayliss and D. H. Deacon


